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THE EFFECT OF CURING METHODS ON COMPRESSIVE STRENGTH AND DURABILITY OF CONCRETE

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ABSTRACT

This research work aimed at studyingfeasibility of using external and internal curing compounds in local conditions. Various curing methods selected for this comparative study are immersion, sprinkling, membrane curing by two different brands of external curing compounds and internal curing by two different compounds. The performance parameters chosen for this evaluation are 7, 28 and 56 days compressive strength, durability and economical analysis for each curing method and appropriate rating procedure is done (Rating evaluation is done with use of interpolation technique). Durability achieved by each curing method, under consideration, is evaluated on basis of percentage water absorbed by concrete block cured by that method. Economical analysis is done by considering different cost such as water charges, labour charges, electrical energy cost, cost of curing compounds related to various curing method.

Various curing methods have been compared by giving weightage out of 100% to each method. As compressive strength is considered most important parameter & it has given 40% weightage. Next to that, percentage water absorption and economical analysis has given weightage of 25% of each and finally 10% weightage is given to initial strength gain. Rating is purely based on above assumption. The rating strategy can be different for different agencies as per their priorities. It is found that the External curing compound gives good result from strength, durability and cost effectiveness point of view. For vertical surfaces, use of external curing compound is more effective than sprinkling.

KEYWORDS: Curing of Concrete; Curing Methods; Curing Compounds.

1. INTRODUCTION:

In order to obtain good quality concrete, placing of an appropriate mix must be followed by curing in suitable environment during the early stages of hardening. Curing is the name given to procedure used for promoting the hydration of cement, and thus development of strength of concrete. Also it is the important process which gives rise to the durability of concrete structure. Even if the importance of curing is well-known to everyone, very few concrete structures are cured in proper way in practices.

Curing can be done by using various methods but these conventional methods have some drawbacks such as improper curing of vertical and inclined members of structures, dependency on unskilled labours for wet curing, water availability issues, time issues & consequent missed

opportunity to gain higher strength & durability. Wet curing methods are labour intensive and labours are seldom aware about importance of curing. In dry areas due to scarcity of water, improper curing occurs. So to overcome these drawbacks, some new curing techniques like use of internal and external curing compounds can be employed. Fresh concrete contains enough water to hydrate cementitious materials but evaporation depletes internal moisture if not properly cured, it allows drying and compromise strength gain and durability.

"Curing of concrete is defined as providing adequate moisture, temperature, and time to allow the concrete to achieve the desired properties for its intended use."

The strength of concrete is affected by a number of factors, one of which is the length of time for which it is kept moist, is cured. Concrete allowed to dry out immediately achieves only 40% of the strength of the same concrete water cured for the full period of 180 days. Even three days water curing increases this figure to 60%, whilst 28 days water curing increases it to 95%. Keeping concrete moist is therefore, a most effective way of increasing its ultimate strength.

Permeability varies extensively over different periods of water curing of cement paste. As we know, by increasing the period of curing reduced permeability can be achieved.

Internal curing is an effective method for improving performance of low water – cement ratio and low permeability concrete because they require additional water to hydrate cementitious materials. In case of external curing (membrane curing) the impermeable coating of the compound is formed on the surface and water loss due to evaporation is controlled to maximum extent. These methods are extremely useful in dry areas, water scarcity areas & for concrete having huge surface to volume ratio.

The Research checked the effectiveness of curing methods using internal and external curing compounds over the conventional curing methods. An economical analysis for all the alternatives, for the local conditions is done.

Effective Curing leads to:-

The increase in cement hydration, promoted by an effective curing, has been shown to increase mechanical properties such as strength and elastic modulus.

An effective curing can also reduce shrinkage, and specifically cracking caused by shrinkage, which can also increase strength and elastic modulus.

Another mechanical property that has shown improvements with effective curing is creep; studies on concretes with W/C of 0.23 with internal curing with expanded slate as curing agent showed less creep compared with normal aggregate concrete on long-term .

Durability of concrete depends on several factors and properties, including permeability, degree of hydration, shrinkage, strength of the cement paste, and presence of micro cracks, among others.

All of them can be improved through an effective curing, whether internal or external.

2. LITERATURE REVIEW:

2.1 Curing methods

1. General

Water curing is achieved by providing water to the concrete surface so that it remains continuously moist. The temperature of water used for curing should be less cooler (about 5°C) than the concrete surface. Otherwise it may give rise to 'thermal shock' that may contribute to cracking. Volume changes due to alternate wetting and drying of the concrete must also be avoided as this may contribute to surface cracking.

Methods of curing concrete fall broadly into the following categories:

- Those that minimize moisture loss from the concrete, for example by covering it with a relatively impermeable membrane (Membrane curing)
- Those that prevent moisture loss by continuously wetting the exposed surface of the concrete (Wet Curing)
- Those that keep the surface moist and, at the same time, raise the temperature of the concrete, thereby increasing the rate of strength gain. This method is typically used for precast concrete products (Wet Curing)

2. Advanced curing methods

a. High Pressure Steam Curing:

In this type, curing is done in a closed chamber. The superheated steam at high pressure (8.5kg/sq.cm) and temp (1750c) is applied on the concrete. This process is called as 'Autoclaving'. Used for precast blocks, lightweight concrete products, cellular concrete products. Advantages are total strength gain in one day or

less time, high resistance to sulphate attack and freezing , thawing. Lower drying shrinkage, low efflorescence.

b. Curing by Infra-red Radiation:
It is useful in cold climatic regions. It s claimed that rapid gain of strength can be obtained than with steam curing and that rapid initial temp does not cause a decrease in the ultimate strength as in case of ordinary steam curing . Generally used for hollow concrete products and operated at normal temp like 900c.

c. Electrical Curing:
It is applicable mostly to very cold climatic regions. It s used to pass an alternating current through concrete itself between two electrodes in concrete. Care must be taken that moisture loss should not be there which make concrete dry. It is not economical method as lot of energy is required.

d. Miscellaneous Methods of Curing:-
Calcium chloride is used as coating on concrete, as it is salt shows affinity towards water and insulate for moisture loss. Keeping form work as it is and sealing the joints with wax or epoxy resins or any other compound prevents the evaporation of moisture from the concrete.

e. Internal Curing Compounds:
These are incorporated into the concrete as an admixture hence known as internal curing compounds. They inhibit moisture loss and thereby improve long term strength and reduce drying shrinkage. Internal curing compounds are relatively new and care should be when utilized. They have been used in tunnel linings and underground mines to provide at least partial curing when traditional methods are difficult or even impossible to employ.

2.2 Research Significance
To check effectiveness of internal and external curing compound methods with respect to strength & durability over conventional wet curing techniques. The strength of hardened concrete after 28 days cured by applying external curing compounds is about 80% that of achieved for conventional curing. Economical analysis for different concrete curing methods (Internal/ External curing compound method and wet curing)

It involves experimental work which covers curing method such as immersion, sprinkling, external curing compound and internal curing compounds. These are critically examined with compressive strength, durability by water absorption and economical analysis. Three samples were tested for each method. The external curing compounds used are Curex, Concure W, compound C which are resin based compounds. Internal curing compounds are Millenium 21 and C-Cure.

On the basis of water absorption method we determine the durability with various curing methods. Economical analysis done by comparing total expenditure for the conventional methods such as sprinkling for 14 days, with external and internal curing compounds.

With the criteria considered like compressive strength and durability, it is observed that external compound A and B gives more satisfactory results. Economical analysis shows that external and internal compounds are cost effective than conventional methods.

3. EXPERIMENTAL DETAILS

3.1 Materials

3.1.1 Cement:-
Ordinary Portland (43 grade) cement was used. It was tested as per the Indian Standard Specifications IS: 8112-1989. Various properties/test are given in Table-1.

3.1.2 Aggregate
Artificial Sand having 4.75 mm maximum size particle was used. It was tested as per Indian standard (IS-383-1970) and satisfied its requirement. Various properties of fine aggregate are given in Table 2. Locally available crushed coarse aggregate having maximum size 12.5 mm was used. Passing % from 12.5 mm sieve was (90–100%). Passing from 10 mm sieve was (40–80%) and passing from 4.75 mm sieve was (0–10%). Testing of coarse aggregate was done as per (IS: 383-1970). Various results are given in Table 3.

Table 1 Physical Properties of Ordinary Portland Cement. (IS-1489 Part 1)

Physical Properties	IS-1489:1991	Test Result
Soundness Le-chat Expansion	10.0 max	5.4
Setting Time Initial Time	30min	55
Final Time	600max	320
Compressive Strength (MPa) 7 Days 28 Days	 22 33	 36 47.8
Specific Gravity	3.15	3.15
Standard Consistency (%)	35%	32%
Fineness	10 Max	7

Table 2 Physical Properties of Fine Aggregates (IS: 383-1970).

Properties	FA
Specific Gravity	2.73
Fineness Modules	3.59
Water absorption (%)	3.35
Moisture content (%)	0.16
Zone	II

3.2 Concrete Mix Proportions
A Control concrete mixture (M-1) was designed as per (IS: 10262-1982) to have 28 day compressive strength of 25MPa.

Water	Cement	FA	CA
0.5	1	1.736	3.224

3.3. Casting of specimen
The control mix was proportioned as per Indian standard specifications IS: 10262-1982, to obtain a 28-day cube compressive strength of 25MPa. Hand mixing was done for the all the concrete mixes. For conducting the compression test, Cubes, 152.4 mm (6 inches) cubes were cast. All specimens were casted at room temperature. They were open after 24 h, and were put into a water-curing tank.

4. RESULT AND DISCUSSION

4.1. Compressive Strength
Early strength of immersed cured block is less as compared to other curing methods. But final strength is highest among others. Early strength of experimental curing compounds is better than sprinkled cured blocks. External compound 'A' has got highest final compressive strength among all experimental compounds. Internal curing compound I has got highest early strength and satisfactory final strength.

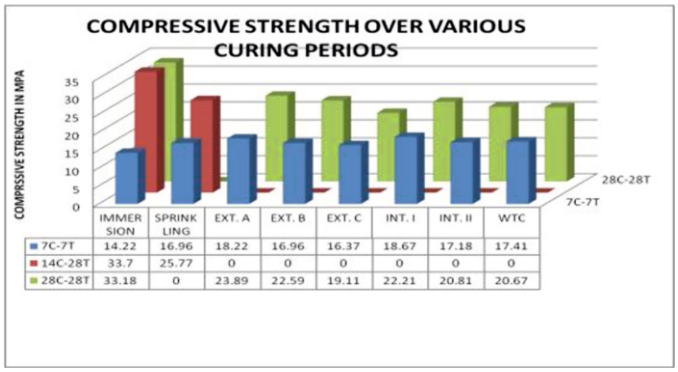

Fig 3: Compressive Strength Over Various Curing Periods

More is the percentage water absorption; more the voids ratio hence less durable concrete.

- Air dried concrete blocks has got more % water absorption.
- Immersed cured blocks have got least % water absorption.
- Among experimentally cured blocks, External B has got least water absorption.

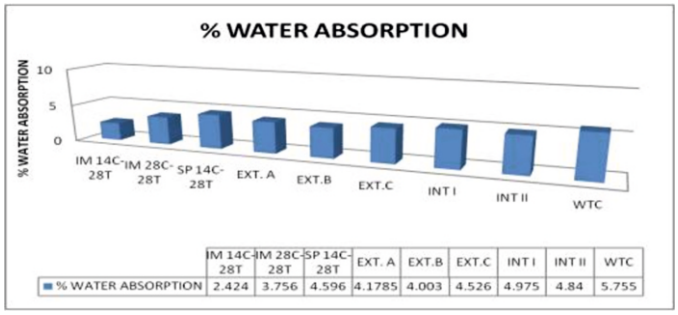

Fig 4: % Water Absorption

5. ECONOMICAL ANALYSIS

5.1 Introduction:
Generally exact cost of curing is not considered during estimation of civil works, but it affects overall economy of the project. Hence cost of different curing methods should be calculated and suitable method should be adopted based upon

strength, durability and optimum cost. Feasibility of curing compounds is checked by economical analysis.

5.2 Salient Features and Assumptions:

1) Same unit (Rs per m^2 or Rs per m^2 per day) has been kept for comparison of all methods.

2) Site Conditions:
- Commercial cum residential building: Vishrambag, Sangli.
- Local readings were taken in summer season.
- Some of the reading, such as water charges, labour wedges may change from place to place and with respect to season.

3) Sprinkling is done for four times in a day.

4) Period of curing is taken as 14 days for all the methods.

5) Mainly focused on curing of vertical surfaces such as column.

6) Site Details:
- Column size : 230×500×3200 mm^3

7) Cost under consideration for comparison of different curing method:
- Electrical energy cost
- Labour charges
- Water charges
- Cost of Hessian cloths
- Cost of equipment like pump, bore etc.
- Cost of curing compounds

8) Comparison between following methods:
- Sprinkling
  - With hessian cloths
  - Without hessian cloths
- External curing compounds
- Internal curing compounds
- Ponding

Table 3 : Economical Analysis

Sr. No.	Curing Method	Cost in Rs./m^2
1	Sprinkling • With hessian cloth • Without hessian cloth	221.42 216.61
2	External A(Curex)	26.71
3	External B(Concure W)	21.71
4	External C	34.52
5	Internal 1(Millenium 21)	28.10
6	Internal 2(C-Cure)	28.10
7	Ponding	189.83
8	Immersion	171.25

As per above table it is seen that external curing method is cheapest among all other curing methods.

6. RATING CHART:

For preparation of rating chart we divided total 100 % weightage into four sub-groups as compressive strength (40%), water absorption (25%), economical analysis (25%), and Initial strength (10%).

As compressive strength is considered most important parameter, it has given 40% weightage. Next to that, % water absorption and economical analysis has given weightage of 25% of each and finally 10% weightage is given to initial strength gain. Rating is purely based on above assumption. The rating strategy can be different for different agencies as per their priorities.

Table No. 4- Rating Results

Curing Method	28th day comp. strength MPa (40%)	%Water absorption at 28th day (25%)	Economical Analysis (25%)	Initial strength gain (10%)	Total (100%)	Rank
Immersion 28C	40	25	8.21	1.25	79.71	I
Sprinkling	20.07	9.926	3.125	5.941	46.71	VII
External A	16.89	17.42	24.44	8.080	61.32	III
External B	13.66	20.57	25	7.837	61.23	II
External C	5	11.18	23.56	10	44.86	V
Internal 1	12.71	3.13	24.28	9.672	41.51	IV
Internal 2	9.228	5.55	24.28	9.366	29.14	VI

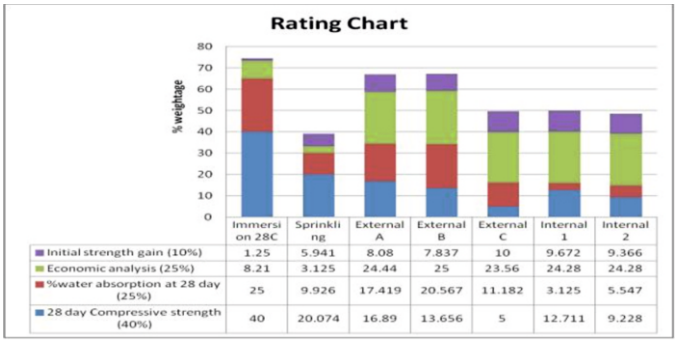

Fig. 5 Rating Chart

7. CONCLUSIONS

The conclusions obtained from this Research are as follows:

- External curing compound gives full proof 80% strength of hardened concrete than that of conventional curing method.
- Initial strength gain is better in case of curing by using internal curing compound than other curing methods.
- With the criteria considered like compressive strength, durability, Economic analysis and Initial strength gain, it is observed that External curing compound Curex (Compound A) is best amongst all other curing methods considered.
- External curing compound C and internal curing compound II are discarded because it gives not satisfactory results.

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